Subject: WRC 03 Agenda Item 1.5

PARAMETERS FOR AN AGGREGATE MODEL ANALYSIS OF SHARING BETWEEN RADIO LOCAL AREA NETWORK (RLAN) DEVICES AND METEOROLOGICAL, RADIOLOCATION AND AERONAUTICAL RADIONAVIGATION RADARS OPERATING IN THE RANGE 5250-5725 MHZ

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1 Summary

Frequency band sharing between radar systems and RLANs is being considered in a number of fora. In order to facilitate the analysis and decision making WECA has developed two documents: one that describes a model for considering the aggregate characteristics of a population of RLAN devices and the resulting parameters for analyzing the potential impact of large scale RLAN deployments (this document) and a sharing analysis (separate document) that considers a number of different radar systems and applies the RLAN characteristics contained in this document.

Note this document makes use of RLAN deployment and operational figures that are extrapolated from current market trends and data. As market trends evolve and as more data becomes available, these figures may have to be adjusted.

2 Introduction

ITU-R Recommendation M.1461 specifies an interfering signal to radar receiver noise power level (I/N) of –6 dB as the required protection level for the radiolocation service. This baseline interference criterion is considered in this study. US submission to Working Party 8B document USWP8B02/10R2, dated April 2nd, 2002 is available as a composite of possible characteristics of radar systems which may operate in the 5GHz band at the present time or in the future. The USWP8B02/10R2 document is used as a baseline for possible radar characteristics since we are aware of no available ITU document identifying *specific* radar systems with their associated characteristics operating in the 5GHz bands in the U.S. or internationally. The bands of operation of RLAN devices in this study are 5150-5350MHz and 5470-5725MHz. This paper will consider sharing between airborne, maritime and ground based radars and a projected population of indoor and outdoor RLAN devices concentrated in a dense urban deployment area surrounded by suburban and rural areas. The RF and operational characteristics of RLANs designed per the IEEE 802.11a specification is used throughout this paper.
This document is organized as follows: 3. Link Budget and 4. RLAN Aggregate Analysis.

3 Link Budget

3.1 Analysis of RLAN - Radar Interference

The primary goal of this model is to facilitate an analysis of the potential interference experienced by various types of radar systems due to a large population of co-channel RLANs. In principle, the calculation performed to reach this goal is the sum of the energy from each of the co-channel RLANs. The potential interference from each RLAN is found through a traditional link budget analysis and, therefore, it is worthwhile to start by discussing these link budgets in some detail. The link budget analysis is undertaken using the inputs specified in the following sections. The basic link budget contains values such as power, line loss, etc. which are specific to individual RLANs and radar systems. Factors such as projected, aggregate, RF characteristics of a distributed population of RLAN transmitters as well as operational characteristics and deployment details of radar systems operating in the 5 GHz bands are added to extend the link budget to an aggregate interference analysis. The likely propagation characteristics between ground-based and airborne radar systems and the nearby population of RLANs, will be key factors in predicting potential future interference levels.

3.2 General Characteristics of the RLAN Population

The modeled RLAN deployment is comprised of a distribution of RLAN devices in the quantities expected at some future date (perhaps 5 to 10 years) in a typical US city (as detailed in a later section). The population of RLANs in this model is predominantly comprised of access point and client devices. Examples of client devices are PC Cards for notebook computers, adapters for desktop computers and embedded or plug-in RLAN devices in handheld adapters deployed in corporate networking, public access and home applications.

Based on current trends for deployment of 802.11a-based technology, it is forecasted that future populations of 5GHz RLAN devices will be dominated by transmitters installed in notebook PC's used in corporate, public access and home environments used indoors. Access point devices in quantities required to provide coverage for the population of mobile clients will also contribute to the population of transmitters.

Average power levels for the population of RLAN devices are estimated by considering the proposed peak regulatory power levels (from CEPT, these are 200mW EIRP peak in 5150-5350 MHz and 1W peak EIRP in 5470-5725 MHz) and then considering the limiting factors which will determine the actual power levels which can be attained by the mix of RLAN device types populating the deployment under study.

The following sections detail the forecasted and estimated characteristics of the population of RLAN devices used in the related sharing study. Note that the values presented below represent predicted worst case values for RLAN operation and aggregate deployment based on current technical and market data and trends. Therefore, these forecasted values may need to be adjusted in the future to reflect latest trends in RLAN usage and deployment.

3.3 RLAN PARAMETERS – INDIVIDUAL

The following parameters for individual RLAN devices are based on expected average characteristics of a large population of devices comprised mostly of access point and client devices used in corporate networking, public access and home applications.

- Average Transmitter Power Determined by Regulatory Conformance Testing

At the present and in the future, the majority of RLAN products are expected to be designed and tested for compliance with regulatory conformance regimes in multiple regions (including North America and Europe). Conformance test methods differ but North American and European test standards impose a series of power limitation tests (such as spectral mask, band edge limits, spurious emissions and peak transmit power limits). As a result, the majority of RLAN devices are configured and sold with average transmit power levels with moderately to significantly lower levels than the peak power level dictated by the standard. Typical reduction below the regulatory limit may vary between 2 to 5 dB. **A conservative power reduction for use in this study is taken as 1dB.**

- Average Power Reduction due to Practical Limitations of RLAN Device Host Systems

In addition, the majority of RLAN devices comprising the population of this study (i.e. RLAN devices in host notebook computers) are affected by the engineering limits of available host power as well as practical antenna gain limits. Prescriptive power specifications for most notebook computers prevent 5GHz RLAN PC Cards or embedded modules in host notebook systems from operating at the highest power limits allowed by CEPT. Also the small form factor of PC Card antennas presents a practical limit of perhaps 3dBi for the antenna gain. These factors serve to limit the transmit power levels below the regulatory limits referenced by CEPT in both 5150-5350 MHz and 5470-5725 MHz bands. In the 5470-5725 MHz band, the population of RLANS in host notebook computers will achieve power levels significantly less than the 1W EIRP upper limit. Over time, engineering developments should serve to reduce these engineering limitations. However, it is reasonable to forecast that the dense population of RLANs studied herein, must include a large contribution of legacy RLAN hardware such that the above mitigation to overall power levels has an impact. **A conservative power reduction for use in this study is taken as 1dB.**

- Average RLAN EIRP

Considering the power reduction factors above, a nominal value of 125mW EIRP (21 dBm) is used as the individual transmit power of the future population of RLANs. This value is derived from the CEPT 200mW Peak EIRP regulatory limit mitigated by the two factors above.

- Average Power Reduction due to Transmit Power Control (TPC) Feature

Implementation of a TPC feature would result in an effective 3dB reduction in transmit power across the RLAN population. **The current study *does not* take into account this potential 3dB mitigation**. Any use of TPC would improve the sharing situation between RLANs and radar systems.

- Dynamic Frequency Selection Feature (DFS)

The current study *does not* take into account the inclusion of a radar detection feature in the population of RLANs. However, this study does consider that all 5GHz RLAN access points currently on the market implement channel-quality-check functionality which results in a uniform spreading of RLAN operations across all allowable channels. Continued presence of this basic functionality is expected as National Administrations (e.g. U.K.) enact rules that explicitly require this channel spreading functionality.

- Transmit Bandwidth (MHz)

A nominal transmitter bandwidth of 18 MHz is used in this study. Although some variation may occur between different RLAN implementations, the average value for a future population of devices is expected to be 18 MHz based on the spectral mask requirement in the IEEE 802.11a specification. (See IEEE Std 802.11a-1999 (Supplement to IEEE Std 802.11-1999), section 17.3.9.2.)

3.4 RLAN PARAMETERS – AGGREGATE

The following parameters describe the expected characteristics of a large population of RLAN devices comprised of access point and client devices used in corporate networking, public access and home applications.

- Ratio of Client devices to Access Points

An aggregate ratio of total RLAN client devices (PC Cards, Handhelds, desktop hosts) to access points is given as 15. This figure considers typical ratios of clients for corporate and home environments of 6 to 22 (to one access point) and public access configurations of 20 to 101 (to one access point). Note that the 802.11a standard dictates Carrier Sense Multiple Access of the RF medium, which results in occasional collisions, but generally a single RLAN device transmitting data at any one time in a cell.

- Ratio of Indoor to Outdoor devices

An aggregate ratio of total indoor RLAN devices to outdoor devices is given as 75 to 1. Based on current market trends, a large majority of RLAN deployment is expected to be comprised of corporate or commercial installations, public access and home use. Usage in those environments is dominated by indoor deployment of access points with indoor mobile users. Public access usage is expected to continue to be dominated by café's, hotels, train stations, restaurants, airport terminals and other gathering places of laptop-equipped-users (i.e. indoor environments). Outdoor point-to-point and point-to-multipoint applications are expected to be relatively small contributions. Although, current trends may show ratio of indoor to outdoor devices to be much larger, a conservative figure of 75 to 1 (or 99%) indoor is used in this study.

- Percentage of RLANS Powered-On

An aggregate percentage of total RLAN devices powered-on at one time is estimated at 33%. In a dense urban environment, all members of the predicted maximum population of RLAN devices are not in-use at any one time. A large number of RLAN devices in this scenario are mobile, laptop devices. These users will power-off the host system while traveling between home, work or public locations. Also, the mobile workforce, by definition, will spend significant time away from the office and out of the area of study. Desktop or laptop host systems primarily kept on desks in corporate or commercial locations will be powered off for significant periods of time (after hours, employee absence or host system suspend or standby mode when idle).

- Radio Sleep Mode

An aggregate percentage of time that RLAN client devices cease transmitting and enter a sleep or idle state is estimated at 20%. This is a power saving feature of most client

RLAN devices where the device enters an idle state during normal operation when no transmit or receive traffic is present. The access point transmits a beacon (usually < 1ms) and "sleeping" RLAN clients may cease transmitting for 100ms periods. This feature is implemented in most client RLAN devices but the timing is not strictly dictated by the 802.11a standard. An estimate of the aggregate sleep time across a future population used in this study is 20%. This factor does not produce a major impact on the end result of the model.

- <u>Active RLAN Duty Cycle</u>

The aggregate percentage of time that any single device in an access point/client group is transmitting is estimated at 10%. Duty cycle is defined here as transmit time divided by (transmit + non-transmit time) for the active RLAN device in a cell. Some corporate users of current 802.11b RLAN technology informally observe average duty cycle per client device in the range of 1 to 5%. The significantly faster data rate of 802.11a technology is expected to sustain lower average duty cycles. Higher than average duty cycles will occur in certain locations where streaming video applications over RLAN devices are operating. But much of the time, an RLAN client device will function at quite modest duty cycle considering the nature of intermittent PC to Internet or PC to server activity. Considering that 802.11a can support MPEG2 or SDTV streams using just 6 Mbit/s of the 54 Mbit/s capacity of a single channel, it is not expected that higher sustained duty cycles will exist across any appreciable geographic area. Therefore, this study considers that multiple RLAN networks, distributed across the geographic area described later, will converge to an average duty cycle in the range of 5 to 10%. A 10% value is used in all calculations.

- <u>Channel Spreading</u>

CEPT spectrum allocation rules in the 5GHz bands makes available 19 channels to be randomly and dynamically assigned by RLAN access point devices. Current manufacturers providing 802.11a technology incorporate functionality to spread operation across all available channels. In addition, industry trends indicate that the majority of devices will be dual-band devices, able to operate in either the 5 GHz band, or in the three channels available in the 2.4 GHz band. Therefore, in this study, **the energy from the population of RLAN devices is divided across the 22 available channels in the combined 5 GHz and 2.4 GHz bands**.

2.5 LOSSES

Consideration of losses is a key factor in the analysis. The losses considered are itemized below. They are related to the losses described in ITU recommendation M.1461.

Free space propagation path loss (FSL)	- the main contribution of the path loss L_P of M.1461
Excessive Path loss (EPL)	- added to the FSL for the L_P of M.1461
Bandwidth Reduction Loss (BRL)	- this is the OTR of the FDR from M.1461
Building Shadowing Loss (BSL)	- Included in the L_P of M.1461
Other Smaller Losses	- includes the L_T and L_R of M.1461

- Propagation Path Loss

A free space loss (FSL) is used for this analysis. The equation for the free space loss is:

$$FSL(R) = \left(\frac{\lambda}{4\pi R}\right)^2$$

For comparison, an urban propagation loss model is contrasted to a free space loss. Such comparison is relevant in any study of propagation through a dense urban area consisting of both terrain and large collections of intervening buildings and structures. An example of the free space loss (FSL) for the direct path through an ambient atmosphere and that through obscured terrain, called urban propagation loss (UPL) here, is illustrated in Figure 1 [1]. The loss through an urban or a surface environment is significantly larger than through clear air. For example, the urban propagation loss shown in the following plot is based on the NTIA Irregular Terrain Model (ITM) using default terrain parameters. (See version 1.2.2 of the ITS Irregular Terrain Model available at http://elbert.its.bldrdoc.gov/itm.html.) The UPL shown here is illustrative of that expected for urban propagation. In addition, the Hata/Okumura propagation model is discussed with respect to Building Shadowing Loss (BSL) below.

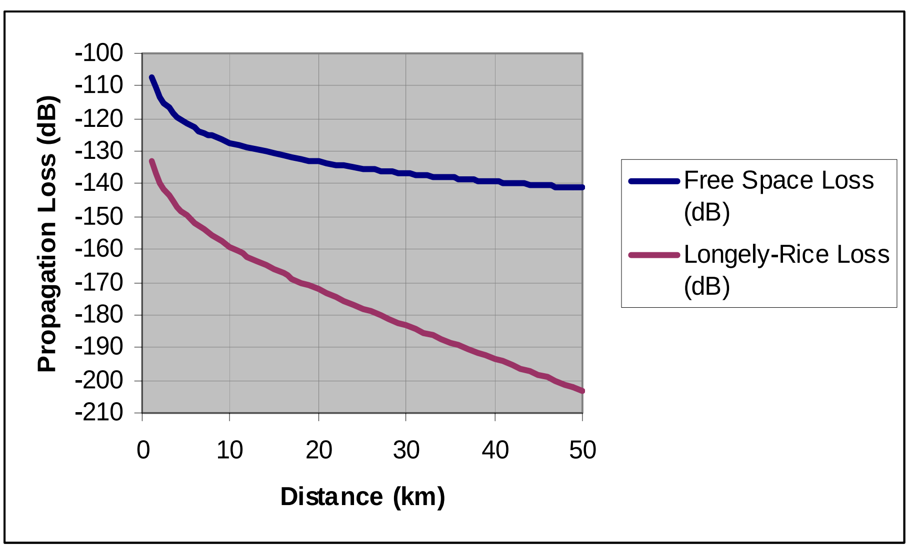

Figure 1: Free Space Loss (FSL) and Urban Propagation Loss (UPL)

[1] What is plotted in this figure as the Longely-Rice value is the free space path loss plus the term known as “aref”. According to the documentation for this algorithm, aref is “the median attenuation relative to a free space signal that should be observed on the set of all similar paths during times when the atmospheric conditions correspond to a standard, well-mixed, atmosphere.”

The parameters used to generate the Longely-Rice curve shown in Figure 1 are listed here.

Parameter	Value
Frequency	5500 MHz
Antenna height 1	3 meters
Antenna height 2	5 meters
Polarization	Vertical
Siting criteria (both antennas)	Random
Terrain irregularity parameter	90 meters
Surface refractivity	301 N-units
Radio Climate	Continental, temperate
Dielectric constant of the ground	15
Conductivity of the ground	0.005 S/m

- Excessive Path Loss (EPL)

An EPL is added for RLANS operating inside homes, offices and public buildings. EPL may be considered equivalent to Average Building Attenuation focused through walls, windows, or floors and ceilings depending on the incident angle. This represents average losses in RLAN signals due to propagation affects inside various structures and the resultant signal if measured immediately outside of the structure. **An EPL value of 13 dB is used for ground based radar scenarios. An EPL of 17dB is used for airborne radar scenarios where radar platform travels directly above the dense urban center.**

- Building Shadowing Loss (BSL)

As discussed above, in urban and suburban environments there will be significant obstruction between buildings containing RLANs and radars. The propagation path between any radar and a population of RLANs is obscured by various surface objects in the area. In a dense urban environment this effect is significant, especially for ground-based radars. Whereas for airborne radars the propagation path tends to be less obscured depending on the distance, altitude and down-look angle of the radar antenna. Therefore, using, the free space loss model, a building shadowing loss is added to account for these propagation effects.

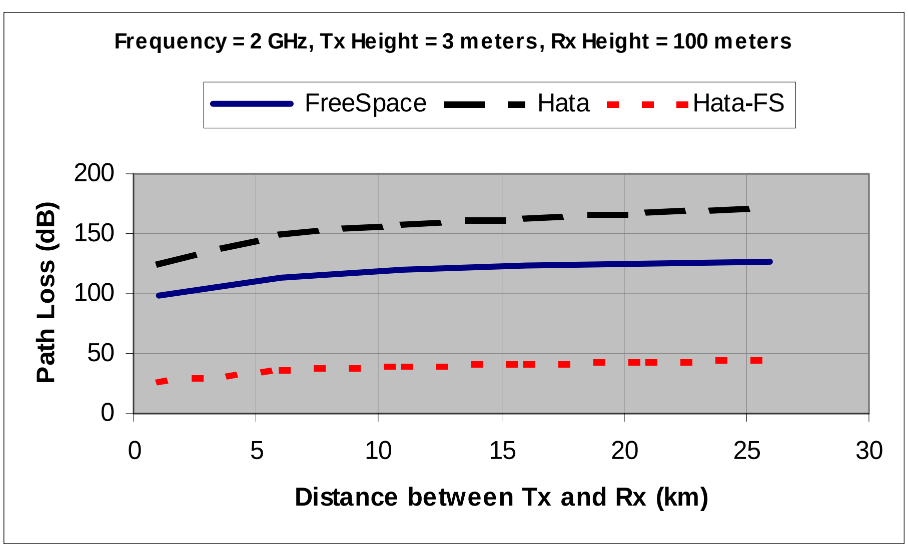

Figure 2: Path Loss difference between Free Space Propagation and the more realistic Hata Urban Propagation Model

The estimate of the possible magnitude of building shadowing loss employed in this study is found by examining the difference between the Hata/Okumura propagation model and the free space model in the 2GHz range in Figure 2. With a radar receiver at 100m height and RLAN at 3m height, separated by 10 km, the difference in propagation loss from RLAN to radar is approximately 40dB greater than Free Space Loss alone. This is illustrated by the "Hata-FS" curve in Figure 2. At greater separations, the additional loss between Free Space Loss and the Hata/Okumura model can approach 50 dB. With the receiver placed at heights lower than 100m, the value will significantly exceed 50 dB. Since this model is derived from empirical data measured by Okumura in actual urban environments, it represents irregular terrain effects as well as shadowing effects from intervening buildings. While the Hata/Okumura model has only been extended as high at the 3 GHz range, the magnitude of the effect it shows is indicative of what can be expected in the 5 GHz range. In fact, the Hata model shows that, for a fixed distance, transmitter height, and receiver height, the difference between the model and free space propagation losses *increase* with increase in frequency.

Therefore, in this study, a Building Shielding Loss is added to the predicted Free Space Loss between RLAN devices distributed in the Urban, Suburban and Rural areas. **A BSL of 35 dB is applied in all ground-based radar scenarios**. A conservative BSL is chosen here to reflect the lowest expected magnitude of Building Shielding due to lack of direct 5GHz loss data in the Hata/Okumura model.

Additionally, **a 6dB BSL is chosen for airborne radar scenarios.** This conservative magnitude of loss is attributed to the diminished yet significant presence of buildings and structures obscuring the paths between RLANs placed in the model distribution areas and airborne radars crossing through the model RLAN population using various antenna down-look angles.

- Bandwidth Reduction Loss (BRL)

A radar may operate with a matched filter bandwidth that is less than the RLAN bandwidth. The nominal RLAN bandwidth is 18 MHz. For an RLAN operating at the radar frequency, the radar will receive all the RLAN power in the radar antenna, but not in the receiver matched filter. **A BRL is calculated and applied.** For example, for a radar matched filter bandwidth of 1 MHz, the bandwidth reduction factor is 12.6 dB. This is effectively a loss added to the RLAN signal. For radar bandwidths that are wider than the RLAN transmit bandwidths this value is not applied.

- RLAN Antenna Gain

The transmitter gain for the RLAN devices was taken to be 0 dBi in the case of ground based radars. That is, the case in which the RLAN signal is aimed in a primarily horizontal direction. For the airborne radar analyses, however, the transmitter gain for the RLAN devices was taken to be – 3 dBi to reflect that the RLAN device antennas are designed to emit their energy primarily in the horizontal direction. Measured data from a representative antenna is shown in Figure 3, measured in the elevation plane.

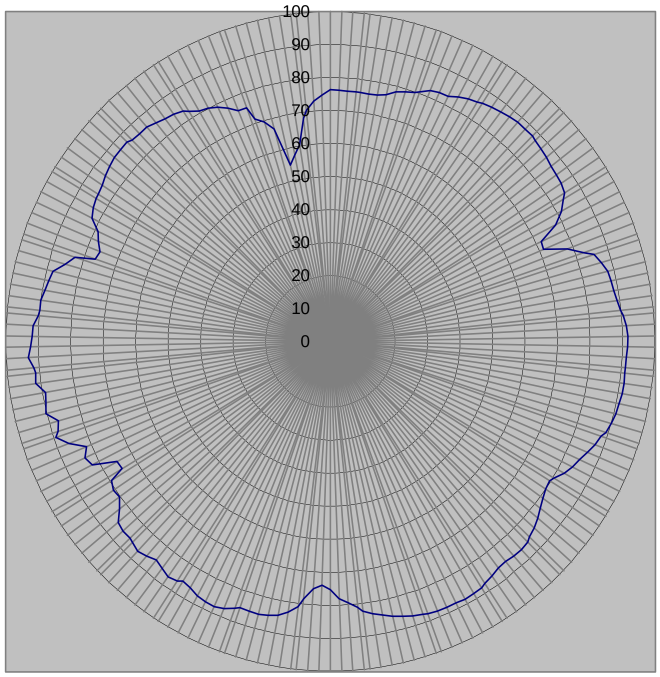

Figure 3: RLAN antenna gain, elevation angle

The data from this measurement show about a 4.8 dB difference between the antenna gain measured out to the side, and the antenna gain measured in an upward direction. **A conservative value of 3 dB difference between the RLAN transmitter gain seen by ground based radars and airborne radars has been used in this analysis.**

- Other Smaller losses

There are other smaller losses, in addition to the FSL, EPL, BRL and BSL that contribute to total path loss. There is an RLAN transmitter to antenna loss. Similarly there is a radar antenna to receiver loss. **A 2 dB nominal value is chosen to represent both of these effects.**

- Losses Summary

A summary of losses applied in this study are summarized in Table 1.

LOSS	Value (dB)	Comment
Excessive Path Loss (EPL)	13	Applied to RLANs located indoors in ground-based radar scenarios. A 17dB value is applied for airborne radar scenarios
Bandwidth Reduction Loss (BRL)	$10\log(BW_{RLAN}/BW_{radar})$ for BW_{radar} < 18 MHz	Value calculated based on radar receiver matched filter bandwidth. Does not apply where radar bandwidth is greater than or equal to nominal 18 MHz RLAN transmit bandwidth
Building Shadowing Loss (BSL)	35	Loss incurred by RLAN radiation obscured from ground-based radars by intervening structures. 6dB value is applied in airborne radar scenarios
Radar Antenna to Receiver loss	2	Incorporated into the radar E.I.R.P value
RLAN Antenna Transmitter loss	2	Incorporated into the RLAN E.I.R.P value
RLAN Antenna Transmitter gain	0 dBi (Ground) -3 dBi (Airborne)	RLAN antennas distribution energy primarily in the horizontal plane

Table 1 Summary of Potential RLAN to Radar Losses

3.5 RADAR PARAMETERS

In the absence of specific radar systems with well-defined characteristics to study, the previously referenced ITU document, USWP8B02/10R2, dated April 2nd, 2002, serves as a source of possible antenna mainbeam and sidelobe gains, beamwidths and operating frequency for radars which appear in the 5150-5350 MHz and/or 5470-5725 MHz bands. These characteristics are required to predict the potential radar receiver interference levels expected from a population of RLANs. A summary of the radar descriptions from Doc USWP8B02/10R2 is included in Table 2. The radars parameters identified in the table below are analyzed in this study.

Radar Identification:	A, C, E, F, G, H, I, J
Platform	**Ground or Ship**
Purpose	Meteorological

Radar Identification:	K, L, M, N, O
Platform	**Ground**
Purpose	Instrumentation

Radar Identification:	P, Q
Platform	**Ship**
Purpose	Surface & Air Search

Radar Identification:	R	S
Platform	**Airborne**	**Airborne**
Purpose	Research & Earth Imaging	Search

Table 2: Radar Characteristics (from Doc USWP8B02/10R2, April 2nd , 2002)

4 RLAN Aggregate Analysis

4.1 Aggregate Geometry Model

An aggregate model for a dense deployment of RLANs is developed below. Using a distributed density of RLANs as defined in the following section, the received power at the radar from the RLANs in a circular ring of depth ΔR at a range R is calculated. Then total power is integrated from a minimum approach range (taken to be 1 km in this analysis), which includes urban, suburban and rural areas as described in later. The received power through the antenna mainbeam and sidelobes are added linearly. This aggregate geometry model is illustrated in Figure 4.

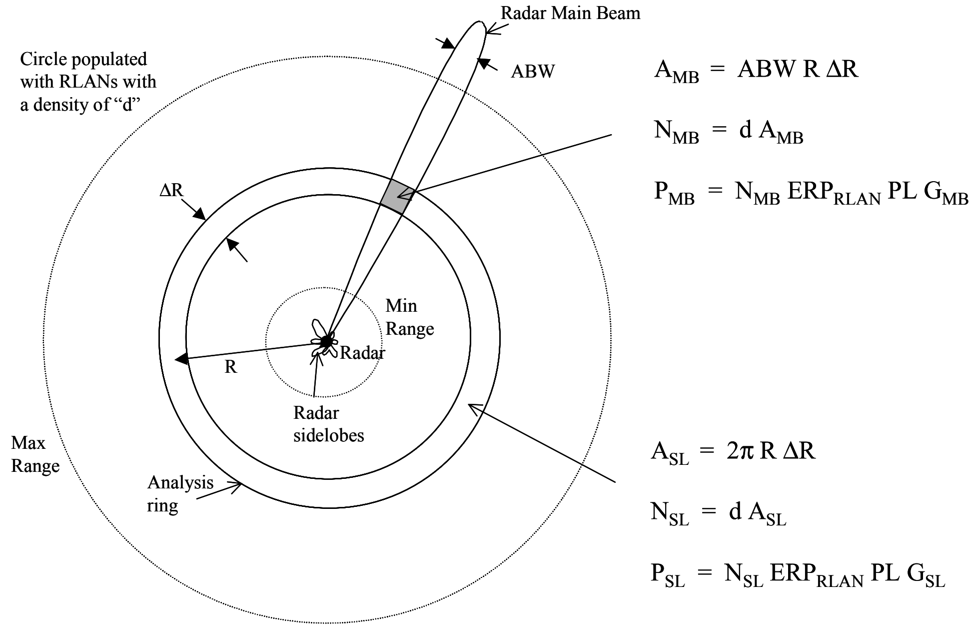

Figure 4 : Aggregate Geometry Model

The list of symbols for the aggregate analysis is:

ABW	=	Radar Antenna 3 dB Beam Width
A_{MB}	=	Area of the mainbeam in ring of width ΔR at range R
d	=	density of RLANs in number per square km
N_{MB}	=	Number of RLANs in the Area A_{MB}
PL	=	Propagation Loss (i. e. free space loss FSL plus other losses)
P_{MB}	=	Aggregate Power in radar receiver from all the RLANs in the radar main beam area
ERP_{RLAN}	=	ERP of each RLAN
G_{MB}	=	Radar antenna mainbeam gain
G_{SL}	=	Gain of the Radar antenna sidelobes
A_{SL}	=	Area of the ring of width ΔR at range R
N_{SL}	=	Number of RLANs in the sidelobe part of the ring
P_{SL}	=	Aggregate Power received through the antenna sidelobes

4.2 Population Density Distribution

The geographic area being analyzed represents a city center surrounded by suburban and rural populations. Since the density of people will be different in those areas, the population is modeled in concentric rings each with a uniform density of people. For our analysis we have used an urban density that corresponds to the densest part of New York City. According to the year 2000 census[2], this density is 66,939 people per square mile, or about 26,000 people per square kilometer. For the suburban density we took as representative Scarsdale, NY with population density of 988 people per square kilometer, and conservatively chose a density of 1500/km^2. The entire state of New York has a density of about 150 people per square kilometer, which we used to provide the order of magnitude of the density in the rural area, and conservatively chose 250/km^2. The areas, densities & total population in each area are listed in Table 3 and Figure 5 below.

[2] http://factfinder.census.gov

	Distance from Urban Center to Outer Boundary of section (Km)	Total Area (Km^2)		Population Density (People/Km^2)		Total People
Urban Section	6	113	x	25,000	=	2,827,433
Suburban Section	20	1,144	x	1500	=	1,715,310
Rural Section	30	1,571	x	250	=	392,699

Table 3 : Population Density Distributions

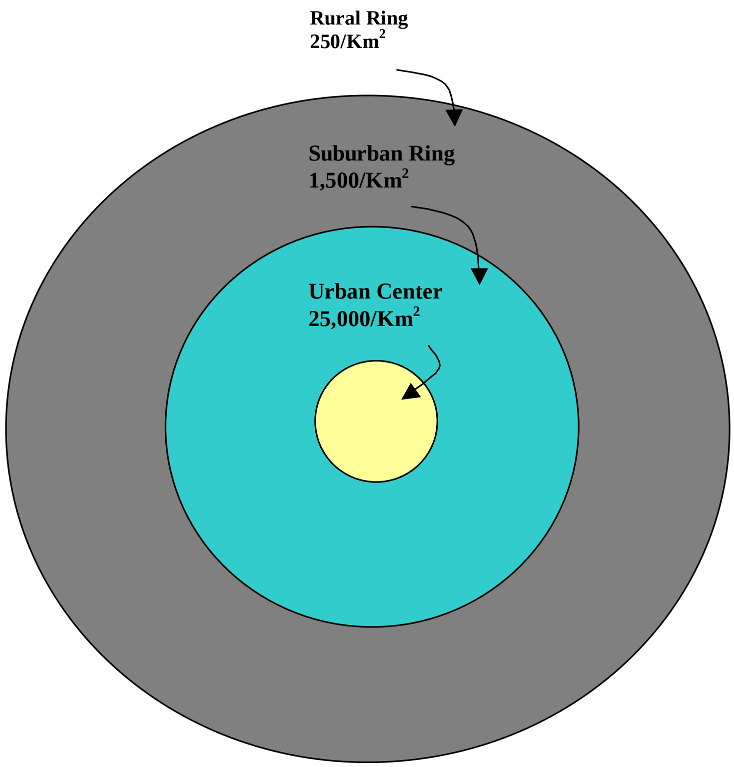

Figure 5: General Geometry and Population Distributions

The density that we have chosen for the urban center in this analysis is a reasonable value based on the size of that center. While it is true that, in localized regions (in an office building, for example,) the density will exceed this value and correspond to the densities used in separate spectrum requirements studies, those higher densities are seen only over very limited geographic areas (on the order of 0.005 km^2 for a single office building.) On this scale, while some areas would have high densities, other areas (streets, sidewalks, alleys, inter-building gaps, parks, etc.) would have very low densities. Since we are analyzing the potential interference levels caused to radar devices by the aggregate number of RLAN devices distributed over a wide geographic area, the appropriate population densities to use are those that correspond to those geographic areas and represent an average of these high density and low density areas. Therefore, we have chosen appropriate population densities based on US Census data.

4.3 RLAN Density

A projection of the total quantities of RLAN devices in the area is derived by multiplying the total population by the projected RLAN market penetration rate (i.e. what percentage of the total population uses an RLAN device). This quantity represents the total quantity of RLAN devices (in use or not) that are present in the area.

But it is the total number of RLAN devices transmitting at one point that contribute to the potential interference received by a radar system. This **average density of transmitting RLANs at the radar frequency** is determined by the factors previously described in section 2.4 including consideration of 802.11a media access which results in only one RLAN in a cell transmitting at one time (apart from occasional collisions). It is this average density of RLANs transmitting at the power level discussed in section 2.4 that contribute to potential radar interference.

The determination of the Ave. Density of transmitters (D_F) is shown in Table 4 below.

Density Variable	Symbol	Urban Value	Sub-urban Value	Rural Value	Comment
Population Density (Urban)	d_P	25,000	1,500	250	per km^2
RLAN Penetration	p_p	0.30	0.30	0.30	30%
RLANs Turned on	p_{on}	0.33	0.33	0.33	33%
RLAN's Not in Sleep Mode	S	.80	0.80	0.80	80%
RLANs Transmitting (Duty Cycle)	p_x	0.10	0.10	0.10	10 %. This is the duty cycle of operation for a Basic Service Set, comprised of an access point an associated client devices.
Client devices communicating with Access Point at one time	C	.0625	0.0625	0.0625	Client to AP ratio of 15 to 1. Therefore, total RLAN devices communicating at one time is 1 out of 16 (= 0.0625)
RLANs at Radar RF	p_f	0.045	0.045	0.045	4.5% RLAN's distributed across 22 channels due to the 2.4 GHz effect
		---------			
Average Density of transmitting RLANs at the radar RF (Urban Region)	D_F (multiply above factors)	0.56	0.034	0.0056	per km^2
Number of co-channel transmitting RLANs at the radar RF	N	63.62	38.59	8.84	Area of region multipled by density of transmitters

Table 4 : Determination of Fully Active (Transmitting) RLANs in a given geographic area

The authors believe the sharing model discussed in this paper is appropriate for sharing studies that consider aggregate energy produced by future populations of RLAN devices. The RLAN parameters in this paper represent worst case predicted values that model the highest expected levels of aggregate RLAN energy in a geographic area.